The Impacts of Aerosols on MCSs Observed during MC3E – Preliminary Results

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Introduction

Aerosol Impacts on MCSs

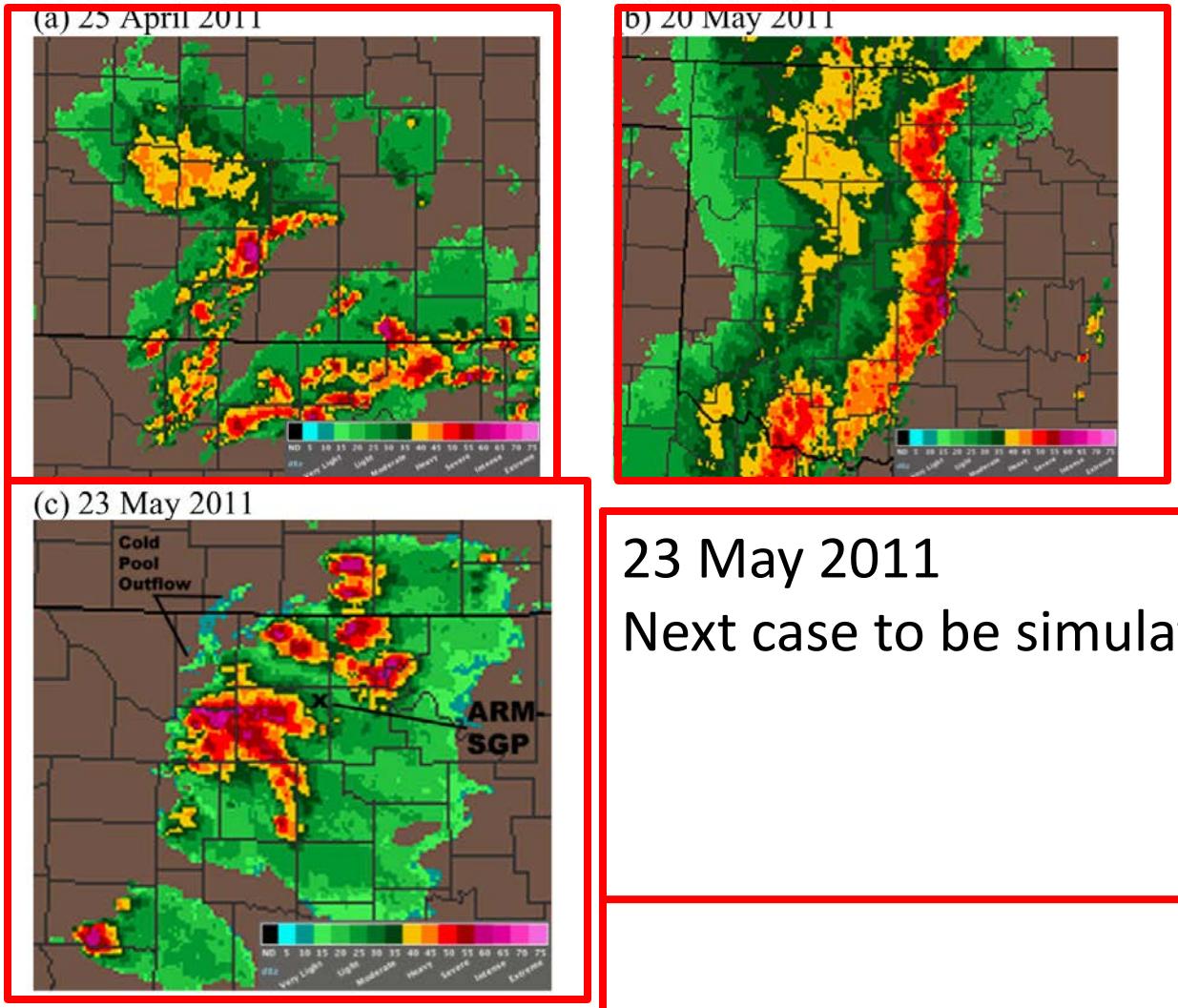
- A number of past studies have investigated AIEs on MCSs (e.g. Lynn et al. 2005a; Wang 2005; Lee et al. 2008; Li et al, 2009; Fan et al 2012; Tao et al 2013)
- More recent studies have examined the impacts of specific aerosol types e.g. dust (e.g. Seigel et al 2013)
- Modeling studies often make use of regionally averaged or "idealized" profiles of aerosol concentrations and types
- MCSs during MC3E
  - range of different aerosol types, concentrations and vertical distributions
  - ideal opportunity to assess relative roles of different aerosols on organized deep convection through use of observational and model output

Goals

1. Aerosol impacts on:
   - Convective-stratiform precipitation partitioning
   - Ice and CRF characteristics of MCS anvils
   - Raindrop size distributions
   - Dynamical features including cold pools and the RIJ
2. MCS impacts on the vertical and horizontal redistribution of aerosols

Case Studies

MC3E Case Studies



23 May 2011

Next case to be simulated

e

MC3E Cases

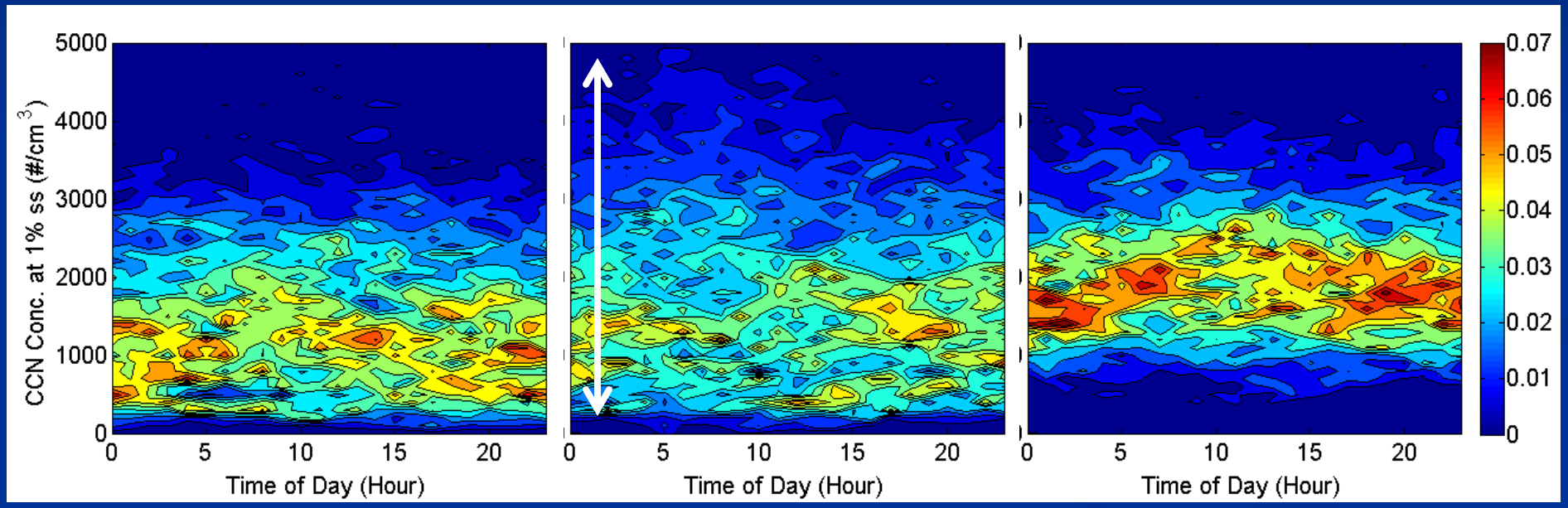
Table 2. MC3E Precipitation Events Identified as Priority Cases for Post Mission Study

IOP#	Date	System	Forecast	Flight Duration
1	21Z April 22 to 08Z April 23	Squall line with leading stratiform	Accurate	ER2: 1919Z on 22nd to 0113Z on 23rd Citation: 2234Z on 22nd to 0057Z on 23rd
2	07Z April 25 to 12Z April 25	Scattered storms	12Z previous day location is off	ER2: 0712Z to 1246Z on 25th Citation: 0921Z to 1222Z on 25th
3	23Z April 26 to 15Z April 27	Scattered storms with stratiform	Location is a bit off, too much cloud	ER2: 0500Z to 1123Z on 27th Citation: 0802Z to 1123Z on 27th
4	09Z May 01 to 21Z May 01	Scattered storms with large stratiform coverage	Accurate	Citation: 1629Z–1842Z on 01st
5	19Z May 10 to 03Z May 11	Scattered storms with stratiform and mixed type precipitation	Location is a bit off, too much cloud	Citation: 2151Z on 10th to 0011Z on 11th
6	12Z May 11 to 00Z May 12	Squall line with trailing stratiform	00Z missed the event	ER2: 1505Z to 1923Z on 11th Citation: 1602Z to 1927Z on 11th
7	07Z May 18 to 15Z May 18	Squall line with leading stratiform	Accurate	ER2: 0512Z to 0955Z on 18th Citation: 0720Z to 0922Z on 18th
8	05Z May 20 to 06Z May 21	Squall line with extended trailing stratiform	19 12Z missed the event, 00Z doing OK	ER2: 1315Z to 1855Z on 20th Citation: 1306Z to 1702Z on 20th
9	20Z May 23 to 07Z May 24	Scattered storms	Accurate	ER2: 2035Z on 23rd to 0235Z on 24th Citation: 2130Z on 23rd to 0041Z on 24th
10	19Z May 24 to 05Z May 25	Squall line	00Z missed the event, 12Z good	Citation: 2018Z to 2228Z on 24th

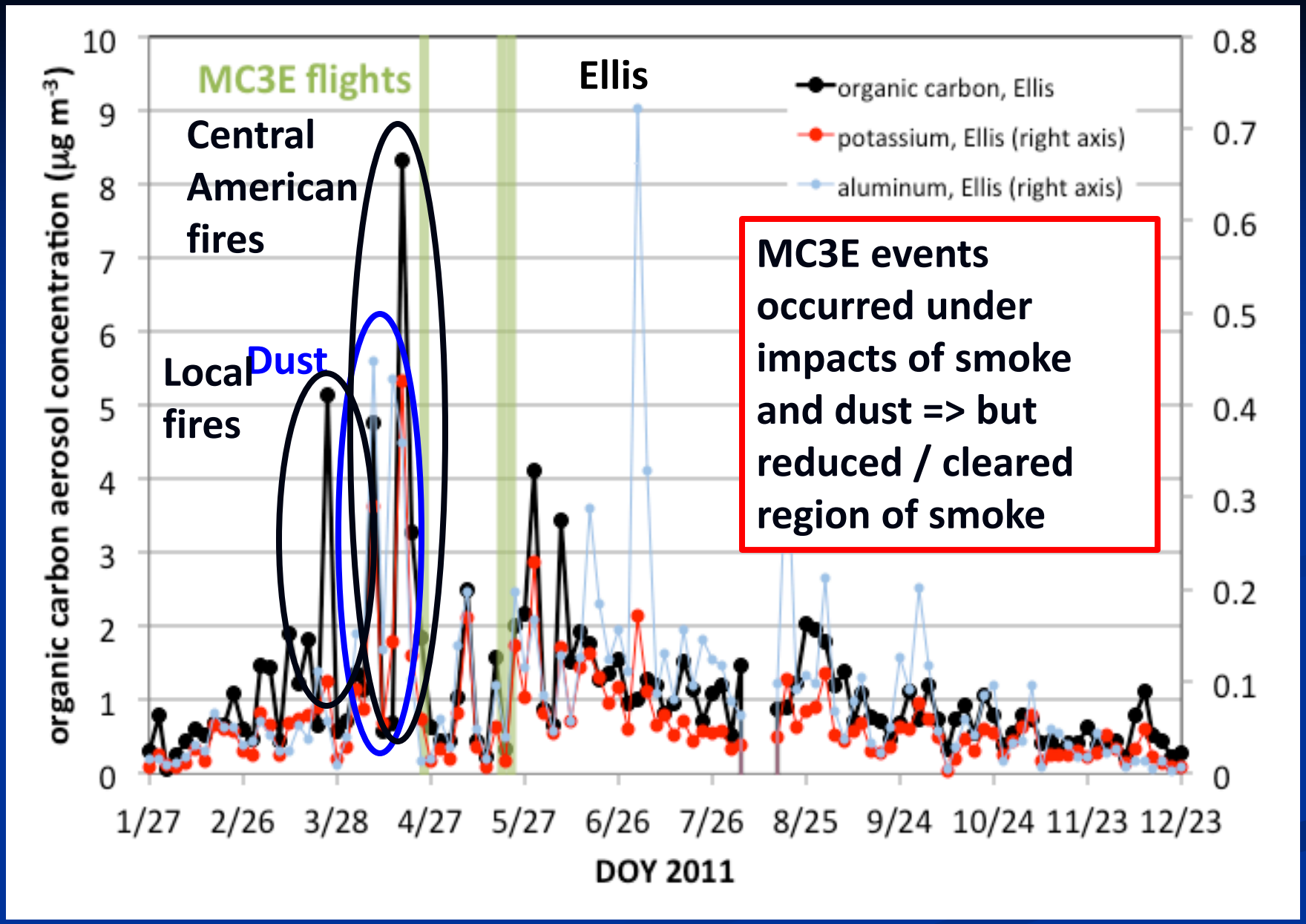
After Tao et al (2013)

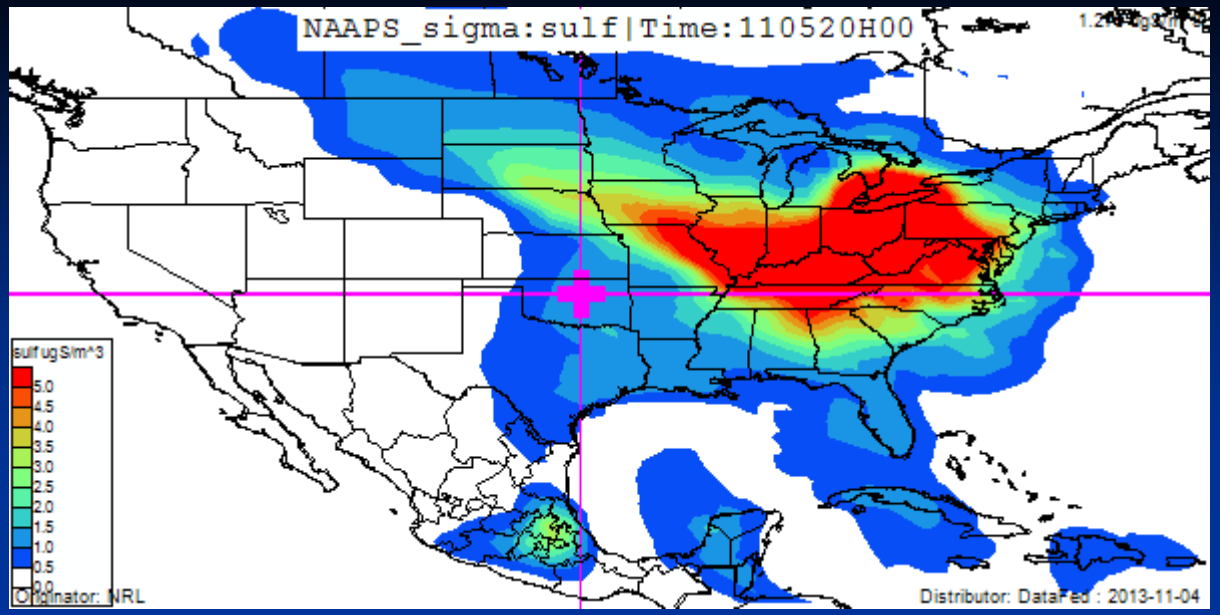
Aerosol Environment at SGP during MC3E Cases

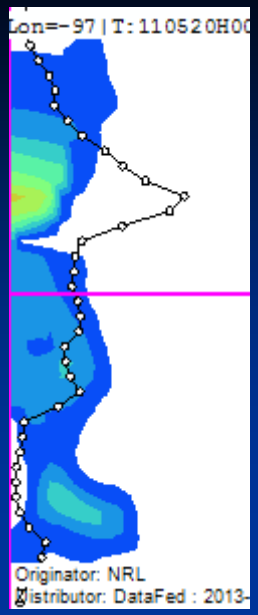
SGP CCN(1%) Frequencies



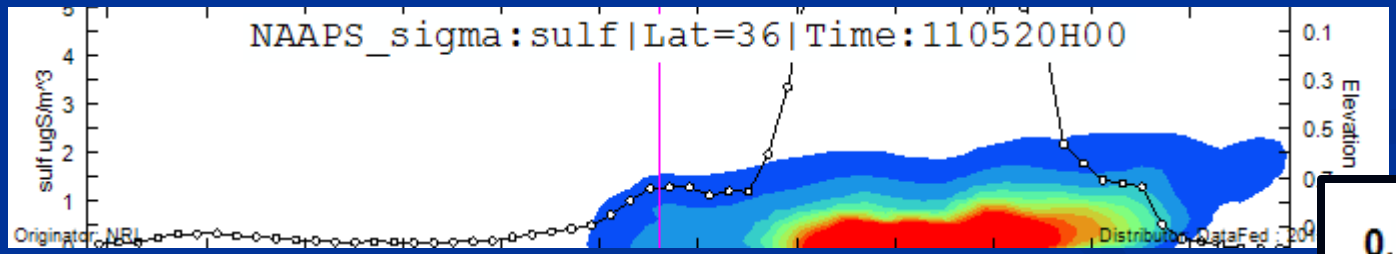
- ARM data at SGP: 2007-2013
- Higher aerosol concentration variations during spring


MC3E flights
Ellis
organic carbon, Ellis
potassium, Ellis (right axis)
aluminum, Ellis (right axis)
Central American fires
Local fires
Dust
MC3E events occurred under impacts of smoke and dust => but reduced / cleared region of smoke
organic carbon aerosol concentration (µg m-3)
DOY 2011
1/27
2/26
3/28
4/27
5/27
6/26
7/26
8/25
9/24
10/24
11/23
12/23



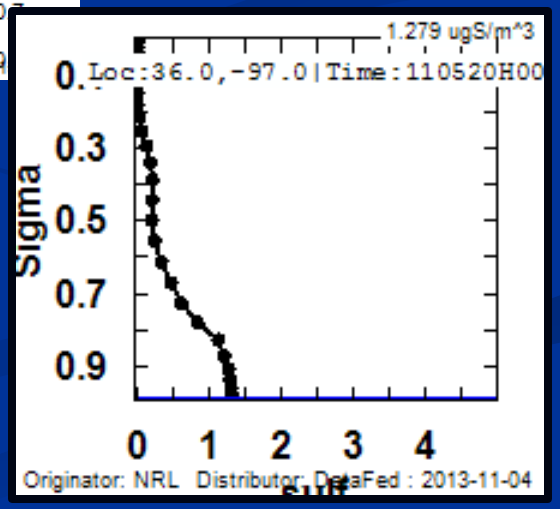


N-S Cross-Section



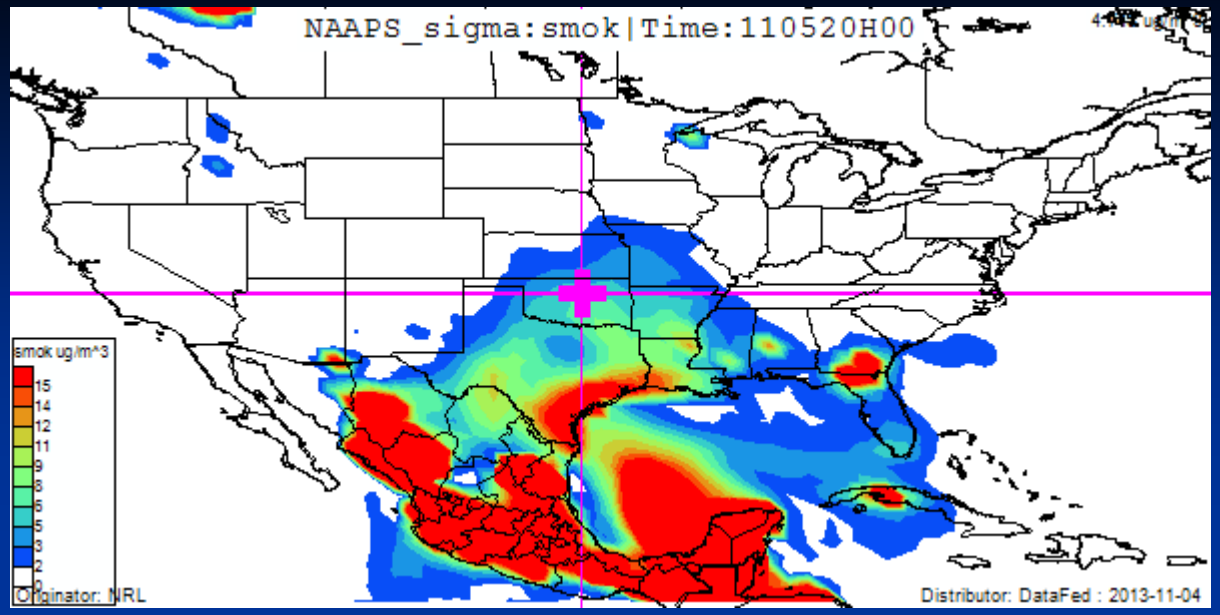
W-E Cross-Section

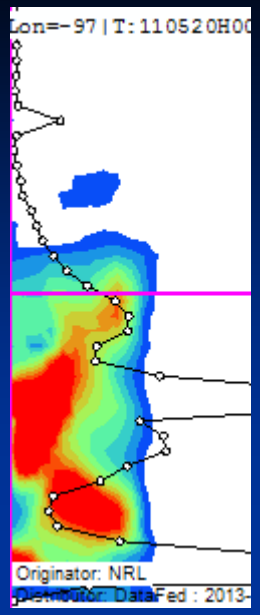
Vertical Profile



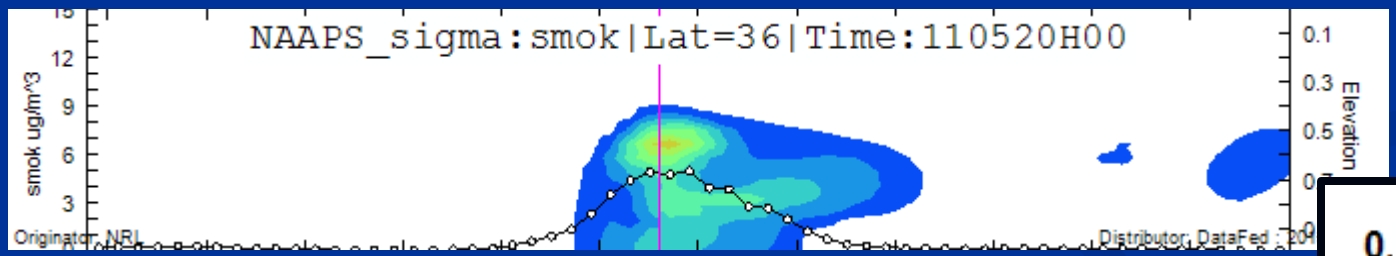
20 May – Sulfate

- Moderate event over eastern USA
- Low-level presence over SGP



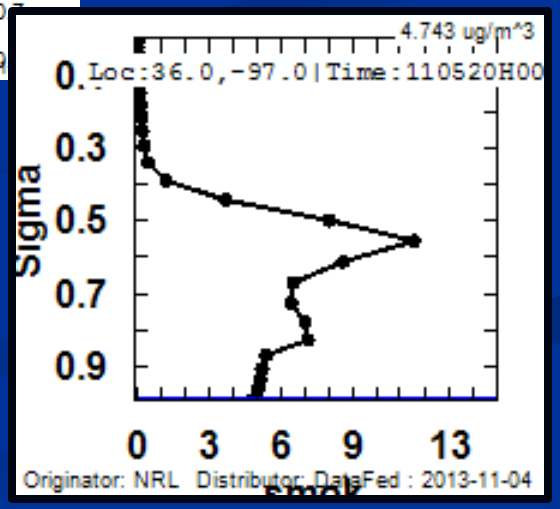


N-S Cross-Section



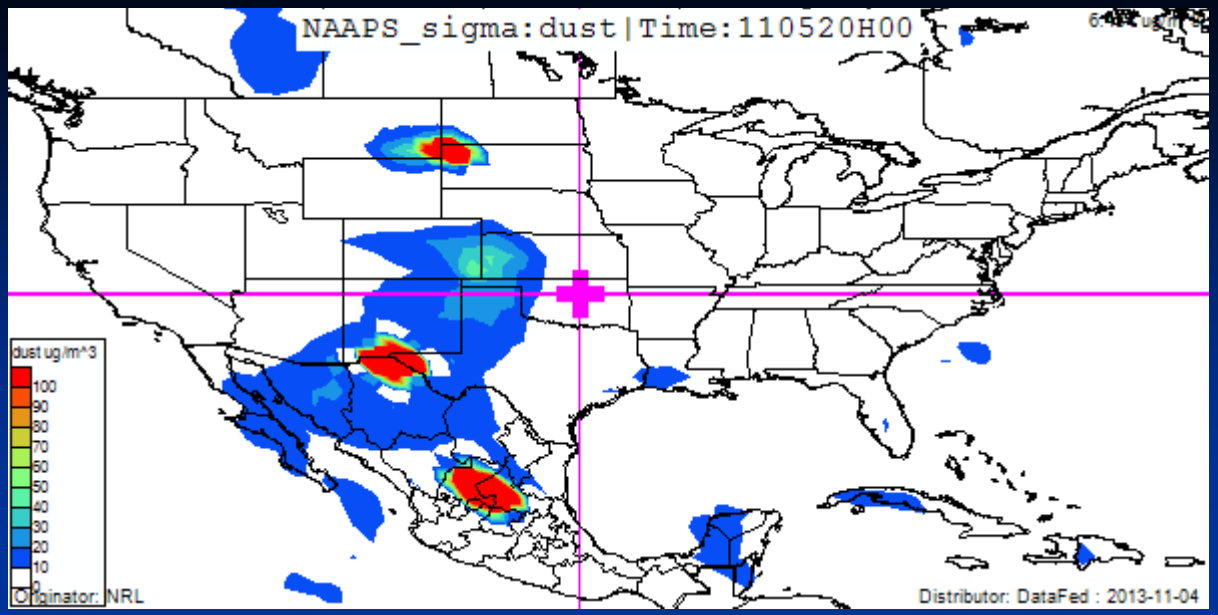
W-E Cross-Section

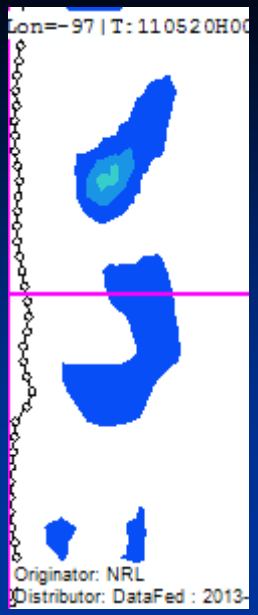
Vertical Profile



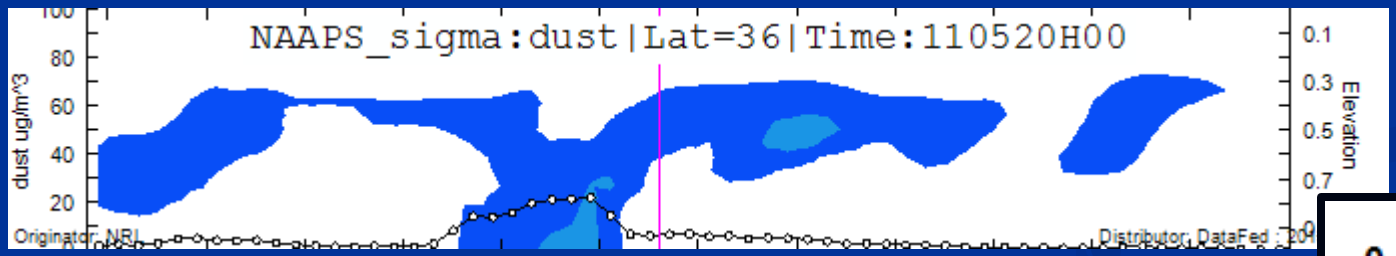
20 May – Smoke

- Transport from the southwest
- Higher concentrations at mid-levels

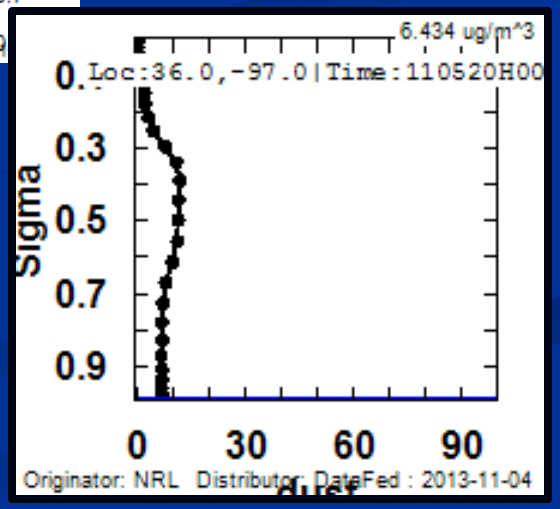




N-S Cross-Section



Vertical Profile



W-E Cross-Section

20 May – Dust

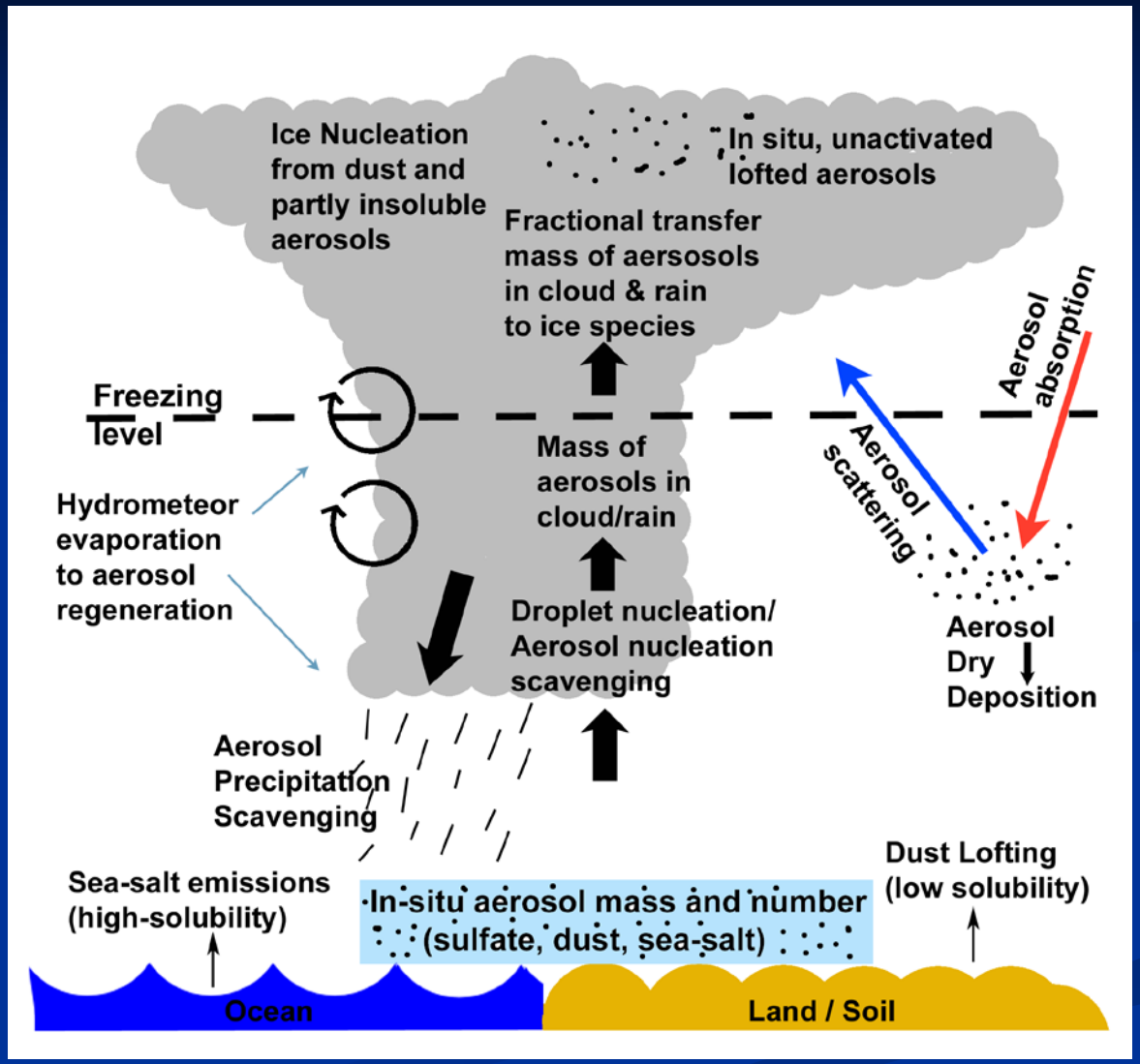
- Concentrations relatively low
- Dust present to the west of SGP

CRM Setup and Experiments

MC3E Case Study – 20 May 2011

RAMS

- Recent extensive modifications to microphysics and aerosol schemes (Saleeby and van den Heever, 2013)
- Aerosol scheme
  - Prognostic scheme
  - Sulfate, dust, sea salt and regenerated aerosol (returned upon evaporation)
  - Next - smoke
  - DeMott et al (2010) scheme



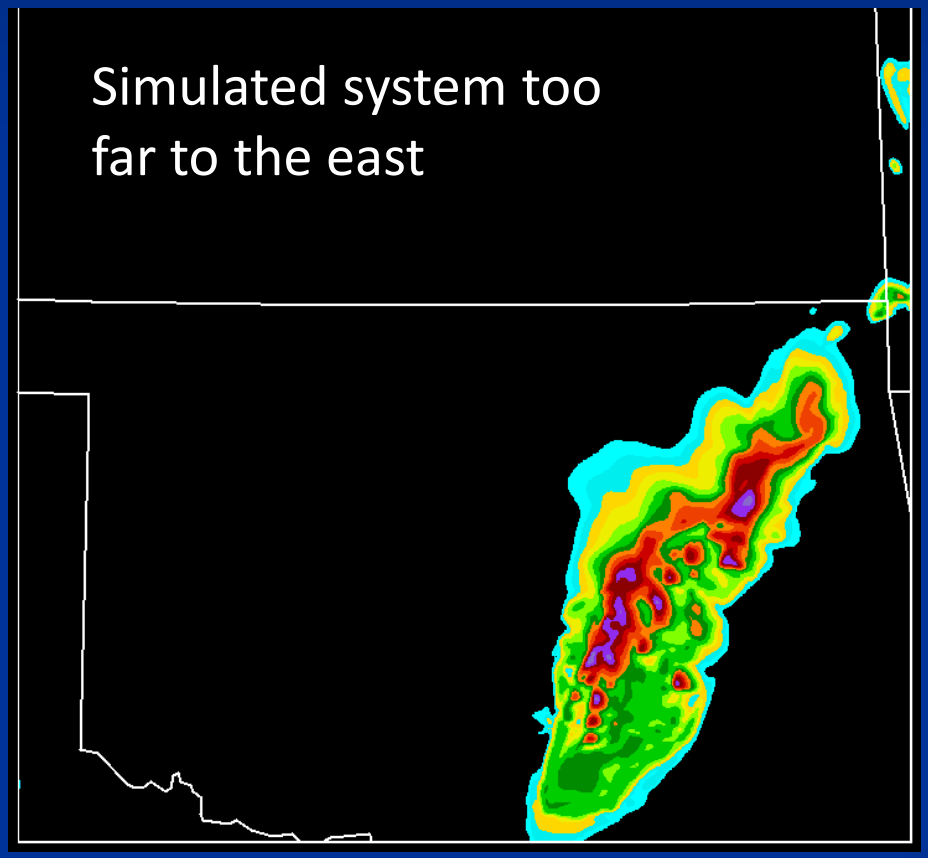
(after Saleeby and van den Heever 2013)

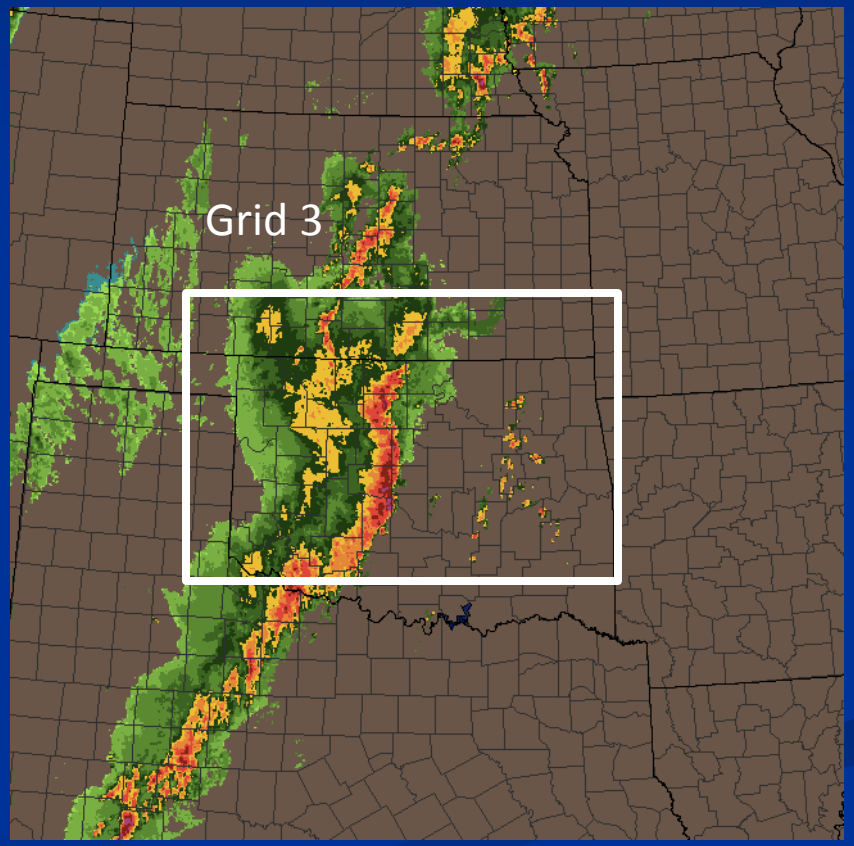
Experiment Setup

- Model grids:
  - Grid 1: dx = 30km (covering most of CONUS)
  - Grid 2: dx = 6km (covering Great Plains)
  - Grid 3: dx = 2km (covering much of KS & OK)
- Step 1: Created "RAMS reanalysis" dataset: 18-21 May
  - Initialized 18 May 0000Z with NARR upper level and soil fields
  - Used lateral boundary nudging and internal nudging
  - Used grids 1 and 2
- Step 2: Conducted CONTROL simulation
  - On 19 May 1800Z, spawned grid-3 from history file and no longer used internal nudging. Ran through 21 May 0000Z.
- Step 3: Ran polluted sensitivity test
  - Aerosol concentration: Clean = 600 cm^{-3}, Polluted = 2000 cm^{-3}
  - For polluted run, inserted aerosols 20 May 0600Z and ran through time of interest from 20 May 0600-1200Z.

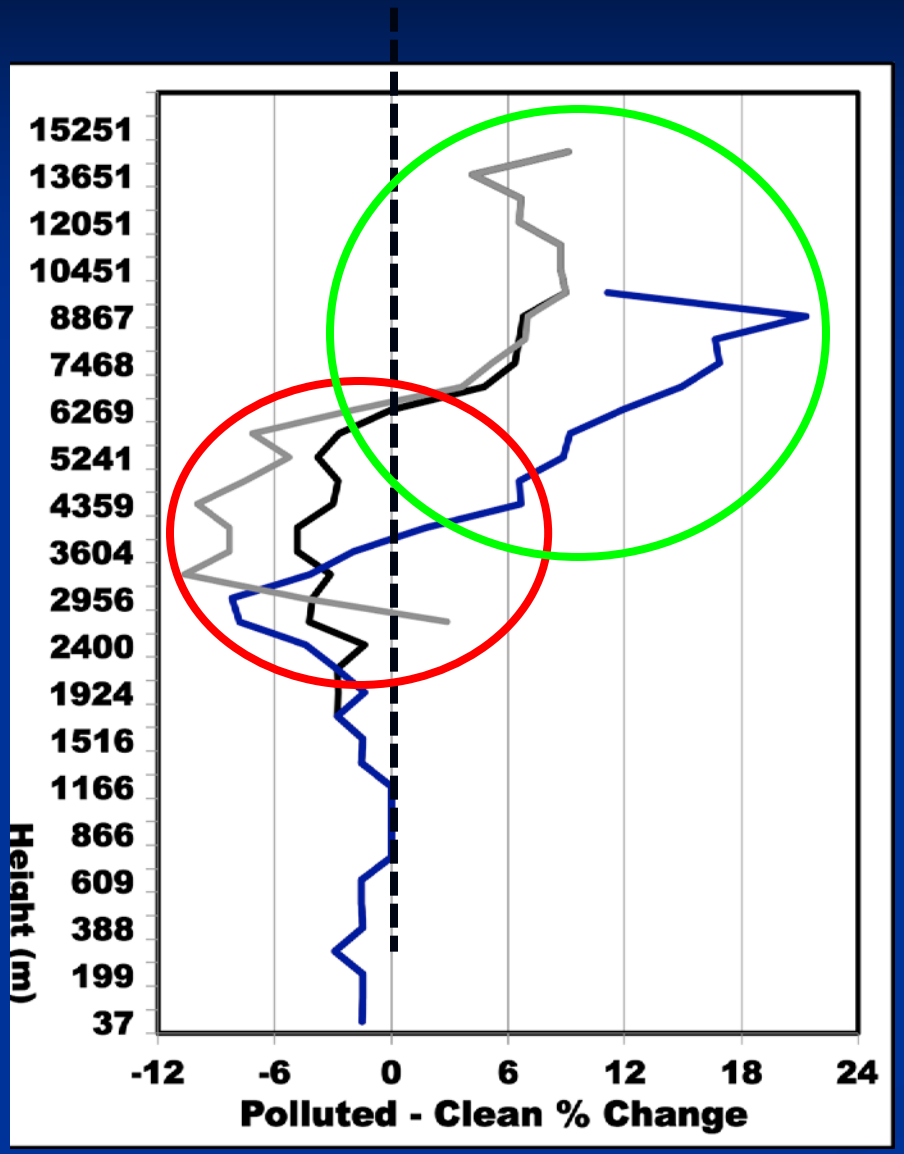
Preliminary Simulation Results

Radar Reflectivity (dBZ) 20 May 2011, 1000 UTC





Condensate Loading



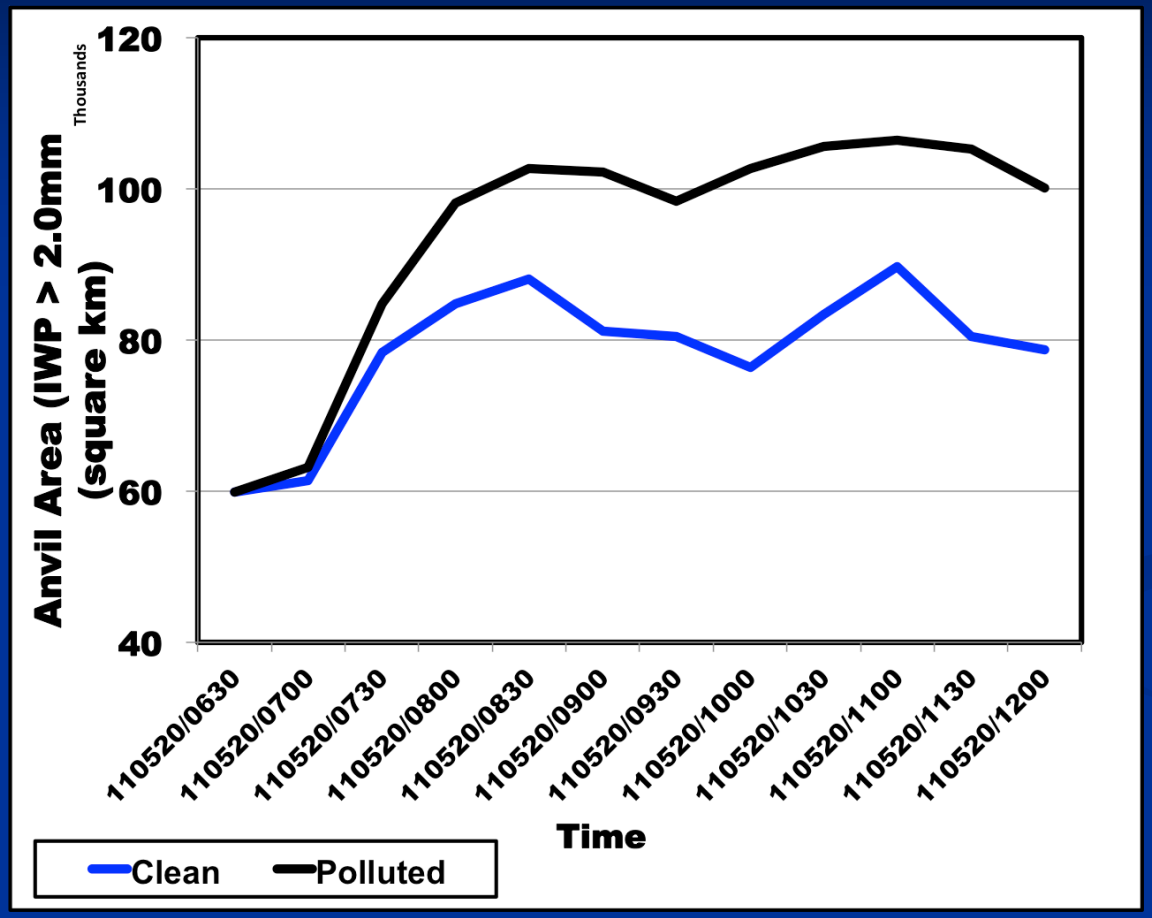
Total Condensate — Liquid — Ice

Cloud droplet nucleating aerosols tend to lead to a decrease in both liquid and ice hydrometeors in the mid-levels and an increase in both at the upper levels of the MCS.

Decreases in mid-levels

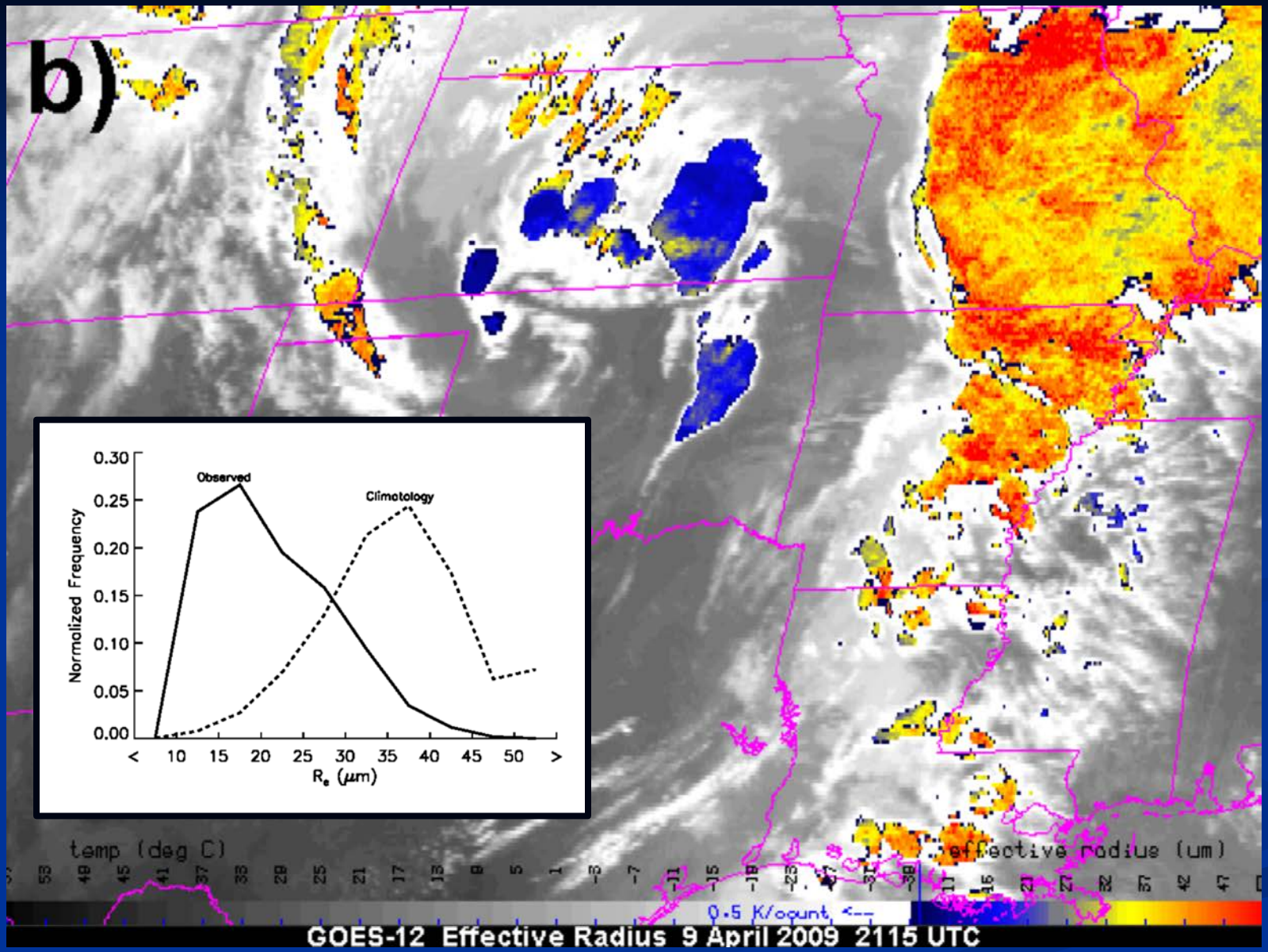
Increases in upper levels

Anvil Areas



Addition of cloud nucleating aerosol leads to an increase in the anvil area.

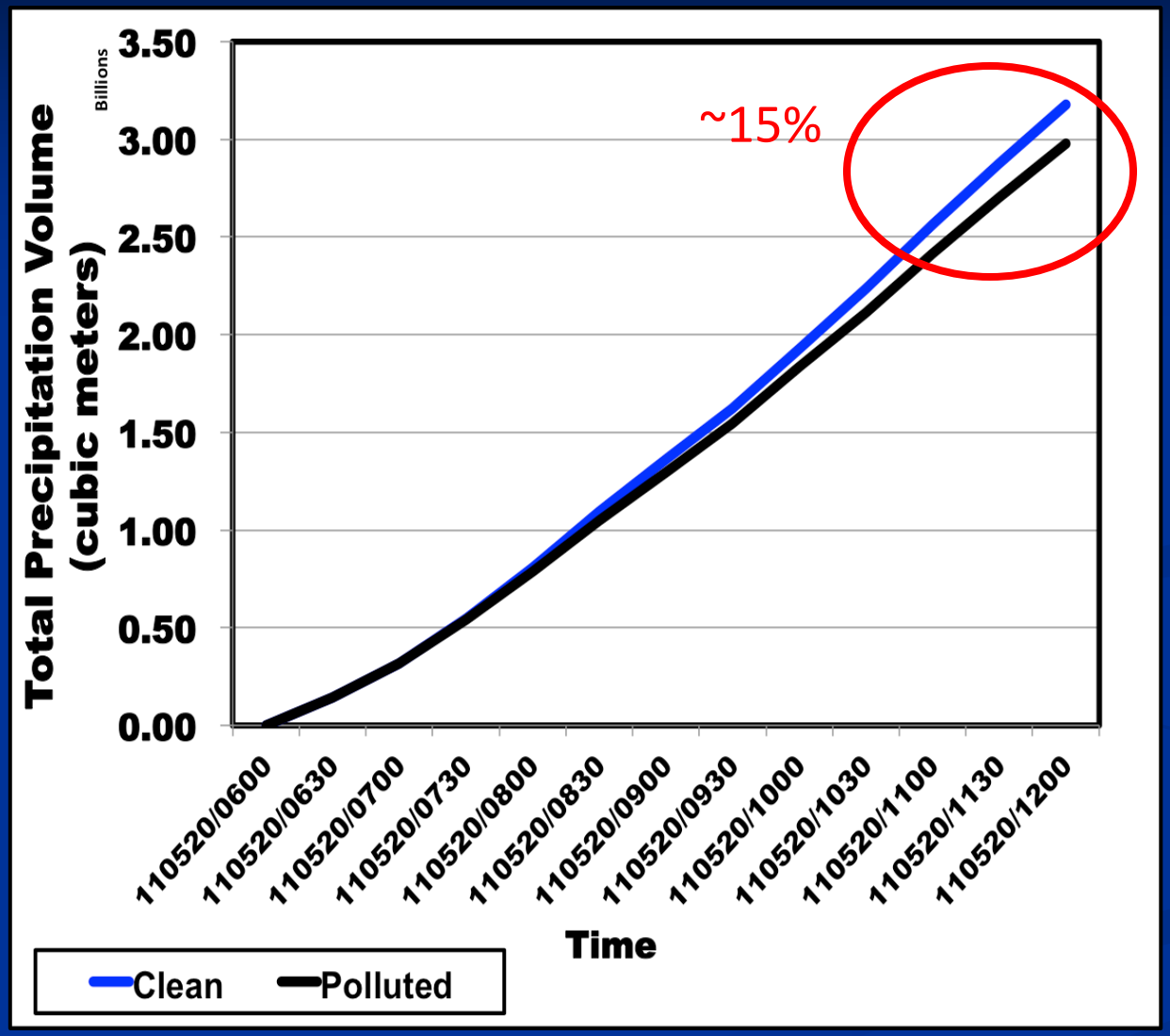
Greater condensate mass, greater numbers of smaller ice hydrometeors => wider, longer-lived anvils



Effective radius defined after Hansen and Travis (1974)

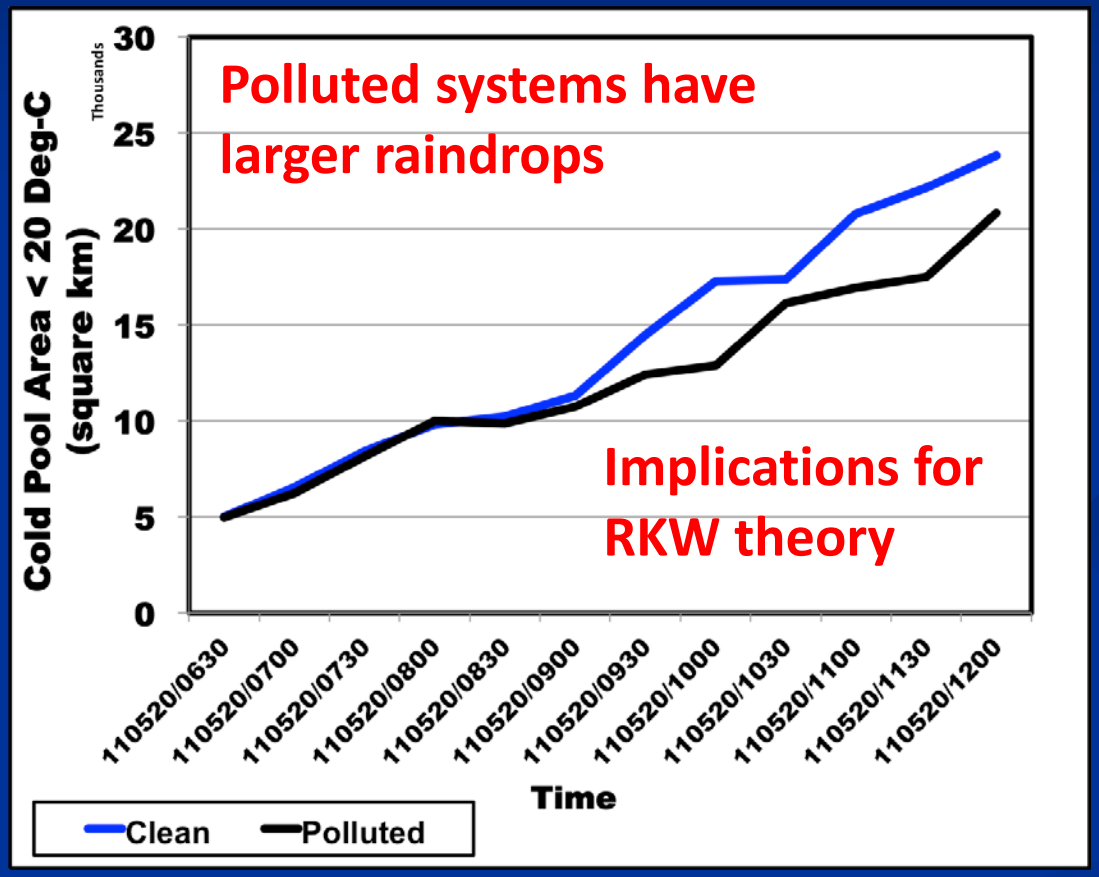
(after Lindsey et al 2010)

Total Precipitation and Precipitation Rate



Increased aerosol loading => reduction in total precipitation volume.

Cold Pool Areas



Addition of cloud nucleating aerosol leads to a decrease in the cold pool area and an increase in the anvil area.

Conclusions and Next Steps

Conclusions

- Range of different aerosols impacting MCS formation of three MC3E cases
- Enhanced aerosol concentrations:
  - Increased cloud water available
  - Increased anvil areas due to lofting of greater condensate mass composed of more smaller hydrometeors
  - Warmer cold pools due to larger raindrop sizes => implications for RKW theory
  - Reductions in total precipitation

Next Steps

- Improve representation of smoke
- Complete all three MC3E simulations
- Extensive model-observational comparisons
- Sensitivity tests in which aerosol types and/or concentrations are varied
- Detailed analysis in order to further address stated goals including convective-stratiform partitioning, cold pool dynamics, RIJ dynamics and cloud radiative forcing of anvils